CAPTURING HAZARDS AND ERADICATING HUMAN ERRORS IN AIRCRAFT MAINTENANCE

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Abstract: *This research paper focuses on specific issues of the aircraft maintenance environment and pleads for a systematic approach in managing human errors. With a continuously growing number of airplanes in service, the maintenance operations are becoming more complex both from increased complexity of the aircraft technology and from the operational perspective. Recent studies show that 80% of the aircraft accidents have as a main cause human error. Maintenance errors play a very important role in this percentage and this is why is significant for the industry to find solutions which can reduce their frequency. It is estimated by certain studies that for every flight hour there are attributed approximately 12 man-hours of maintenance [1]. The paper considers the importance of the maintenance in safe operation of the aircraft and highlights the related maintenance aspects starting with aircraft design phase and continuing with normal maintenance operations. A vital role in avoiding maintenance errors is a proactive approach consisting in identifying hazards in maintenance environment, investigating the issues and proposing solutions to avoid such issues to escalate in undesired outcomes as incidents or accidents. Finally, some mitigation strategies for specific risks in aviation maintenance environment are presented to eliminate and, were not possible, to diminish the human errors.*
Keywords: *aviation maintenance, errors, human factors.*

1. INTRODUCTION

Most of the modern aircraft nowadays have a lot of automation. They are able to fly and even land by themselves. However, the human being role cannot be neglected as it is very critical in most of the phases of an aircraft lifecycle e.g. designs, manufacturing, operation, maintenance and modification. To totally eliminate the human error is impossible as it is impossible to entirely eliminate the failures in a mechanical system, or in other words, to design and manufacture a system with 100% reliability. There is also a proverb which refers to this stating that “To Err Is Human” which makes us to understand that the human error issue was considered long time ago when people realized that despite whatever they do, to eliminate human error is impossible.

In 2003 an International Air Transport Association (IATA) Safety Report found that 26% of the accidents have a maintenance cause event which started the accident chain [2]. According to Boeing (2007), the overall percentage of the human error (including engineers, pilots, air traffic controllers, etc.) causing accidents is approximately 80% [3].

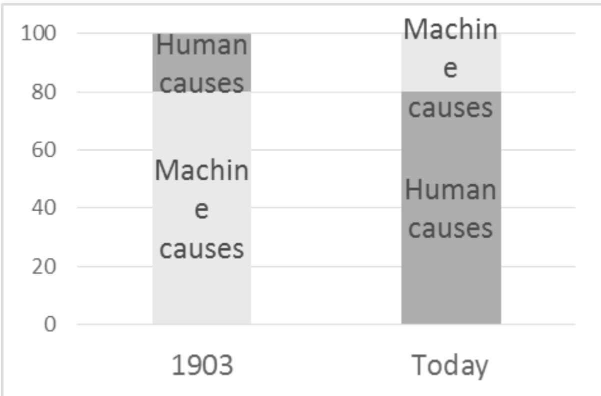

Fig. 1 Causes of accidents (source: adapted from Boeing, 2007)

Human errors are estimated to contribute to over 70% of the accidents in various industries, including nuclear power plant, chemical industry and transportation [4]. In some cases human error can have catastrophic consequences, especially if we consider what can go wrong with a nuclear power plant. In aircraft maintenance, the consequences can also be catastrophic if we consider what can go wrong after improper maintenance on some safety critical systems such as power plant, flight controls, engine controls, emergency backup systems, etc.

The majority of the human activities depend on the task itself, working conditions, and the person himself. With other words, the human activities depend on the context comprising of man, technology and organization (MTO) triad [5].

With a more and more increased safety level demand from both commercial aviation industry and passengers, maintainers have to eliminate as much as possible human errors in aircraft maintenance.

2. THE HUMAN FACTORS ISSUES IN AIRCRAFT MAINTENANCE

History of Human Factors concept in aviation can be traced back in 1970s where it was found under the designation of Cockpit Resource Management and primarily used in pilot training.

The main scope was to train flight crews in order to reduce the pilot errors by making better use of the resources in the flight deck. The name was changed from Cockpit to Crew Resource Management (CRM) to emphasise the focus on cockpit group dynamics [6]. Some airline programs dealt with specific topics such as team building, briefing strategies, situational awareness and stress management [7]. Starting with 1990s, CRM training began to reflect some other factors, such as organizational culture within the aviation system in which the crew must perform their duties.

From aircraft maintenance point of view, the concept was introduced later in 1990s following a series of accidents with serious safety consequences. Among them, American Airlines Flight 191 (1979), Aloha Airlines Flight 243 (1988), United Flight 232 (1989) and British Airways Flight 5390 (1990). All of them have maintenance human errors as a main cause or at least as an important contributory cause to the accident.

From regulations point of view, at international level, ICAO amended Annexes 1 and 6 referring to Personnel Licensing respectively Operation of Aircraft to include human factors considerations in the regulation of aircraft maintenance.

It can be affirmed that human factors issues are related not only to the maintenance stage of an aircraft lifecycle but also to design and manufacture. In Europe, there are specific designing and certification requirements for aircraft used in commercial air transport enforced by European Aviation Safety Agency (EASA) which take into consideration the human factors issues. As for example, AMC 25.783 referring to latching and locking fuselage doors states the following: "*The operating handle loads on manually operated doors should be based on a rational human factors evaluation*." [8]. EASA CS 25.1309 concerning equipment, systems and installations states the following: "*Systems and controls, including indications and annunciations must be designed to minimize crew errors, which could create additional hazards*." [9]. During the design phase human errors must be considered for the maintenance process in order to either make the errors impossible to occur or to reduce their consequences or probabilities of occurrence. Three basic strategies can be considered to prevent errors through design: exclusion, prevention and fail-safe design. Exclusion refers to designing components and systems in such a way that it will be impossible for the maintainer to commit an error (e.g. different size elevator cables fittings). Prevention refers to designing components in such a way that it will be difficult for the maintainer to commit an error, but not impossible (e.g. installation of a check valve which has a drawn orientation arrow on it). Fail-safe design is a concept used in designing aircraft structures and is defined as a structure which can retain a required residual strength for a period of unrepaired use after failure or partial failure of a principal structural element [10]. Related to maintenance error, fail-safe means to design a component in a way that the consequences of an error will be reduced (e.g. a structural element which failed in time due to a missed crack during a maintenance inspection. The remaining structures will be able to carry out the loads for safe operation).

When moving to the maintenance environment, the human error issues are seen from a different perspective compared to design.

The highly complex maintenance environment makes very difficult to find a strategy which will be able to solve the human error problems.

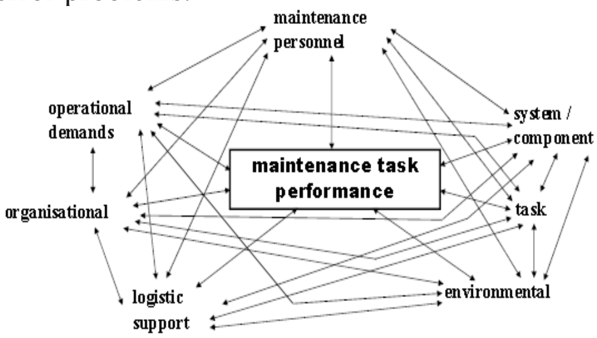

Fig. 2 Factors affecting maintenance task performance (source: Airbus)

Research studies showed which the most error-prone maintenance activities are. Confidential Human Factors Incident Reporting Programme (CHIRP) (2003) mentioned 63% of errors occurred during installation, 12% during servicing and 7% during fault isolation. Airbus (2007) mentioned 72% of the errors occurred during installation and 9% during servicing [11]. UK CAA (2009) concluded in a study analysing 3982 Mandatory Occurrence Reports that 43,7% were incorrect maintenance and 17% were incomplete maintenance [12]. From the above data can be concluded that maintenance errors follow somehow a constant pattern over time and this can be used to make a step forward in dealing with maintenance errors and this will be to make predictions. The lack of such statistical data makes it very difficult at the moment but with the implementation of Safety Management Systems, is mandatory for maintenance organizations to collect data.

The unique maintenance environment makes aircraft technicians to confront with a set of specific human factors issues. The environment is more hazardous than in most of the usual jobs. It involves working at heights or in very tight spaces (e.g. fuel tanks), performing activities in inclement weather conditions (e.g. negative or very high temperatures, wind and rain), working with dangerous materials and tools, working in teams or alone, following procedures and taking decisions, facing time pressure and confronting with unique type of stress.

Compared to pilots and air traffic controllers activities, in which an error will have an immediate impact, maintenance technicians and engineers will know that their responsibility is not finished with the end of the shift and their activity could have an impact minutes, days, months or even years later.

This type of stress is encountered by maintenance personnel. A conclusive example in this direction is the crash of Japan Airlines Flight 123, in August 1985 [13], due to an improper structural repair which happened seven years earlier when the aircraft suffered some structural damage due to a tail strike.

Following the accident, the maintenance manager killed himself.

3. CAPTURING HAZARDS IN AIRCRAFT MAINETANCE ENVIRONMENT

"A hazard is a condition or object with the potential to cause death, injuries to personnel, damage to equipment or structures, loss of material or reduction of ability to perform prescribed function" [14].

Aircraft maintenance environment is highly complex and is almost impossible to think about all the conceivable situations which can appear.

However, maintenance organizations must continuously seek for new hazards in their activities.

When looking for capturing hazards in aircraft maintenance, four main areas can be considered: the individual, the maintenance task, the environment and the organization.

The following aspects can be taken into account for identifying hazards:

- At individual level: fatigue, medical condition (hearing, sight etc.), theoretical knowledge, practical skills, working shift patterns (dayshift/ nightshift), communication skills, attitude towards safety, morale, initial and recurrent training, workload and stress;
- At maintenance task level: complexity of the task, access, working position, repetitive or novel task, availability of the maintenance data, unambiguous maintenance data, availability of specific tools and equipment;

- At environment level: extreme weather conditions, high noise level, insufficient lightning, insufficient environment protection, workplace layout and cleanliness, provision and use of safety equipment, toxic materials, time pressure;
- At organizational level: lack of resources, lack of spare parts and materials, inappropriate equipment, supervision, duplicate inspections, procedures (unclear or not present), reward system, selection of staff and competence assessment, training programs, planning of scheduled maintenance tasks, planning of critical tasks, promoting safety culture;

To identify hazards, the organization has two categories of methods available: reactive and proactive. Reactive hazards identification refers to learning from occurrences that have already happened. Examples are incidents and accidents investigations which can be external (carried out by competent investigation bodies) or internal (carried out by company's safety department). Proactive hazards identification methods are safety surveys, safety audits, safety reporting, brainstorming and safety assessment (e.g. Failure Modes Effects and Critical Analysis (FMECA), Event Tree Analysis (ETA)). A very important role in identifying hazards in a maintenance organization is played by the safety culture of that particular organization, in other words it depends by people, how much importance they confer to safety or how much they believe in it. A safety culture consists of:

- Just culture (everybody is responsible for safety within the organization and people are held accountable for the system);
- Reporting culture (people report, without fear of punitive actions against them, everything they consider as being a safety issue);
- Learning culture (employees in the organization are open to learn and management will be aware that people can improve the system);
- Informed culture (people are knowledgeable about the system and stay connected with it to be updated with changes);
- Flexible culture (people accept changes within the organization and adapt to the system).

All of the above elements of safety culture will impact the process of capturing hazards and therefore the safety performance of the organization. A complex hazard identification program at a maintenance organization level will use a combination of reactive, proactive and predictive methods to improve their safety performance.

4. ERADICATING HUMAN ERRORS IN AIRCRAFT MAINTENANCE. IS THAT AN ACHIEVABLE OBJECTIVE

Eradicating human errors in aircraft maintenance is the most desirable goal in the context of aircraft maintenance, but in reality is simply not possible to consider all the conceivable situations an organization or individual will face during maintenance activities.

Some classical methods, like telling people to pay more attention, or to retrain them, appeared to have very limited effects. Therefore, a more realistic approach will be to manage the errors in a systematic way.

The following approaches can be used as maintenance error management strategies: prevention, reduction, detection and recovery.

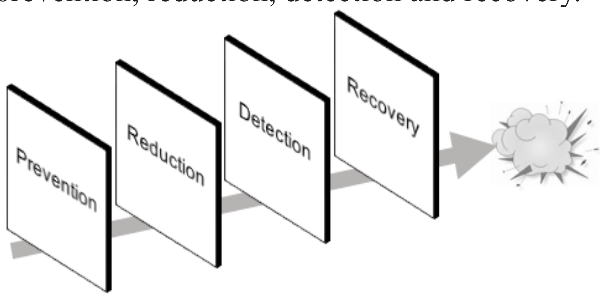

Fig. 3 Maintenance errors management strategies

Prevention as a maintenance error strategy is the most desirable approach, but in the context of real life is not all the time an option.

It aims to fully avoid the error and requires most of the times a design solution.

Avoiding maintenance errors through design can be achieved using technology (e.g. Health and Usage Monitoring Systems (HUMS), Interactive Electronic Technical Manuals (IETMS), software logics and on-board diagnostics).

Error reduction refers to minimizing as much as possible the probability of an error to happen and the consequences of that error. Detection is a strategy which enables the error to be easily discovered by the person who committed it, by another person or by the system. Recovery refers to the capability to return the system to its safe condition easily, as soon as possible after the error was committed.

But to be able to eliminate or to manage an error is important to understand the root cause of that particular error. Understanding the root cause of a maintenance error will enable the organization to take the proper decision concerning remedial actions. Root cause analysis can be used not only post incident or accident event, but also following a safety report, a quality finding or whenever a safety concern is perceived. There are several tools which can be used to perform root cause analysis as for example Events and Causal Factors Charting method, Ishikawa Fishbone Diagram, Management Oversight and Risk Tree Analysis (MORT), Five-Why method and Fault Tree Analysis method (FTA) [15]. The purpose of identifying all the possible causes which led to an error is to find the fact which, if eliminated, would have stopped the event from happening and to find the most cost effective solution to the problem.

The error management will leave two possibilities for the maintenance organization: error reduction and error containment. Error reduction comprises of the measures that a maintenance organization can take to limit the occurrence of errors while error containment comprises measures to limit the consequences of that errors that still occur. Typical constituents of an error management program include measures to:

- discover, assess and eliminate error-producing factors within the organization;
- minimize the error liability of the individual;
- reduce vulnerabilities of specific tasks;
- identify the organizational factors that contribute to error-producing factors at individual, team, task and workplace level;
- enhance error detection;
- make latent conditions more visible and
- increase error tolerance of the system.

Some of the most efficient tools in aviation, proven by the history, available to improve safety performance are technology, training and regulations. Besides that, the maintenance organizations can include quality monitoring, safety audits, inspections, feedback from accident investigation and feedback from reporting system including confidential reporting.

CONCLUSIONS

Human errors can be managed starting with design phase. Prevention is probably the first choice as it will eliminate the error but in reality this is not possible all the time due to compromises in design requirements (i.e. costs, capabilities, safety and aircraft performance).

Modern technologies can aid reduction in maintenance error accidents.

Maintenance organizations have to continuously look for hazards considering at least the following areas: the individual, the maintenance task, the environment and the organization. A functional hazard identification process is reliant on a mature safety culture.

An error can be corrected or its re-occurrence avoided only when the entire background behind that particular error is understood.

Real solutions for improving human performance and avoiding maintenance errors sit with both the maintenance organization and the individual and consist of improving the maintenance environment (e.g. working conditions, procedures and knowledge).

Human errors cannot be fully eradicated but for sure they can be reduced both in frequency and consequences and this can be achieved through the error management approach.

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